

Missouri Department of Natural Resources

Total Maximum Daily Load Information Sheet

Table Rock Lake

Waterbody Segment at a Glance:

Counties: Barry, Stone and Taney Counties
Nearby Cities: Kimberling City, Branson
Size of Impairment: 43,100 acres
Pollutant: Nutrients
Sources: Point and Nonpoint sources

Proposed for addition to 2002 303(d) list

TMDL Priority Tanking: To be determined



Description of the Problem

Beneficial Uses of Table Rock Lake

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life and Human Health associated with Fish Consumption
- Whole Body Contact Recreation (swimming)
- Boating and Canoeing

Use that is impaired

- Whole Body Contact Recreation (swimming)

Standards that apply

- All waterbodies in Missouri are protected by the *general* criteria (standards) contained in Missouri's WQS, 10 CSR20-7.031(3). These criteria (also called *narrative* criteria) list substances that all waters "shall be free from". For example, sections (3)(A) and (3)(C) state:
 - Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
 - Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

Table Rock Lake is an exceptional water resource. It provides unequalled recreational and economic opportunities for Missouri's citizens. It is nationally known for its excellent fishing. It also provides magnificent scenery due to its location in the Ozark Mountains. Table Rock Lake is the centerpiece

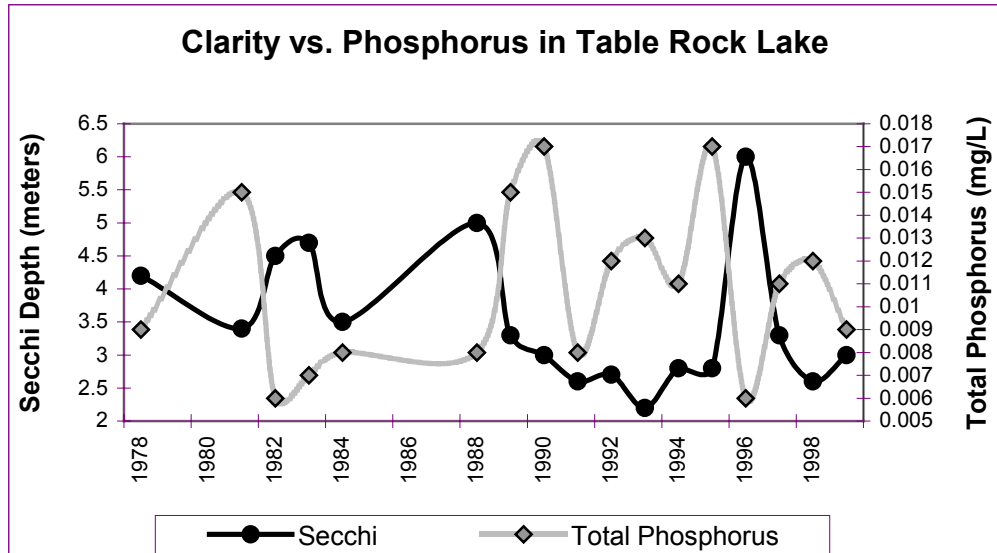
for a wide variety of tourist attractions. The watershed of Table Rock Lake is estimated to produce over a billion dollars in tourism revenue each year.

Table Rock Lake was not included on the EPA approved 1998 303(d) list of impaired waters. In recent years, however, concern has been growing due to reduced water clarity. The problem with clarity is caused by increased amounts of nitrogen and phosphorus entering the lake. Nitrogen and phosphorus are plant nutrients, which can cause excessive growth of algae. Phosphorus has been identified as the chief cause for the increase in algae, which impart a green color to the water and reduce water clarity. This is particularly true in the James River arm of the lake, which receives heavy loads of phosphorus from urban stormwater, wastewater treatment plants and nonpoint sources. Increasing resident populations in southwest Missouri, the large number of tourists visiting the area, commercial and industrial development and livestock production have caused the increased nutrient loading throughout the lake.

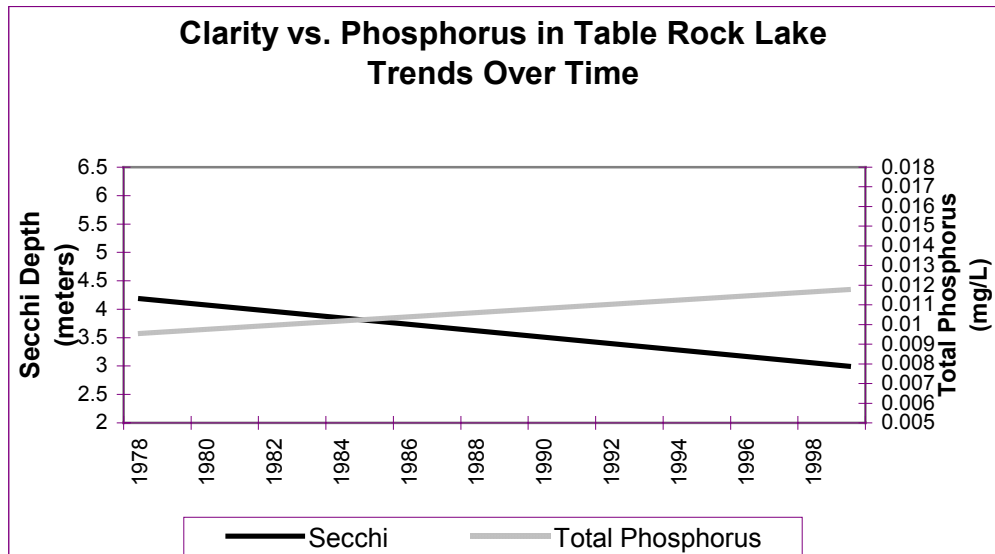
The lake is currently proposed for addition to the 2002 303(d) list. A Total Maximum Daily Load (TMDL) was completed on the James River in 2001 for phosphorus and nitrogen. This will address the decreasing water clarity in Table Rock Lake, as well as the algal growth in the James River. The TMDL calculates the reductions in nutrient loading needed to control algal growth. A phosphorus limit of 0.5 mg/L (milligrams per liter or parts per million) has been established for all discharges into the Missouri portion of the Table Rock Lake basin equal to or greater than 22,500 gallons per day. The largest point source in the basin, the Springfield Southwest Treatment Plant, initiated phosphorus removal from its discharge in March 2001 and has been achieving results much lower than the 0.5 mg/L limit.

Increased phosphorus levels will continue to be a problem, however, even after nutrient loading is reduced. This is because phosphorus attaches to soil particles, which can be washed into streams by erosion. Table Rock Lake acts as a “sink” as the sediment load coming from its tributaries settles on the bottom of the lake. Phosphorus will continue to be released from this sediment for an unknown period of time. Due to this fact, it is impossible to predict when improvements in the clarity of the lake will occur after nutrient target loads are met.

A map of Table Rock Lake and graphs of the data may be found below. The graphs show the distinct relationship between phosphorus and clarity: when phosphorus increases, clarity decreases; when phosphorus decreases, clarity increases.



Source: Dr. Jack Jones, Professor of Limnology, University of Missouri at Columbia



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For more information call or write:

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Kings Lake Historical Reports

The following four excerpts are from the *Draft Table Rock Lake - Total Maximum Daily Load Report*, June 2002, Missouri Department of Natural Resources.

Table Rock Lake

Region - Ozark Highlands

Table Rock Lake is a 43,100 acre Army Corps of Engineers reservoir located in southwest Missouri. This lake is in the White River system and is preceded upstream by Beaver Lake in northwest Arkansas. The lake consists of a long, winding main branch and three major arms. Kings River and Long Creek flow north out of Arkansas to enter Table Rock Lake while the James River flows south from the central Ozark Highlands Region. The majority of the lake's watershed is forested, but development around the lake and urban areas on the lake's tributaries threaten water quality.

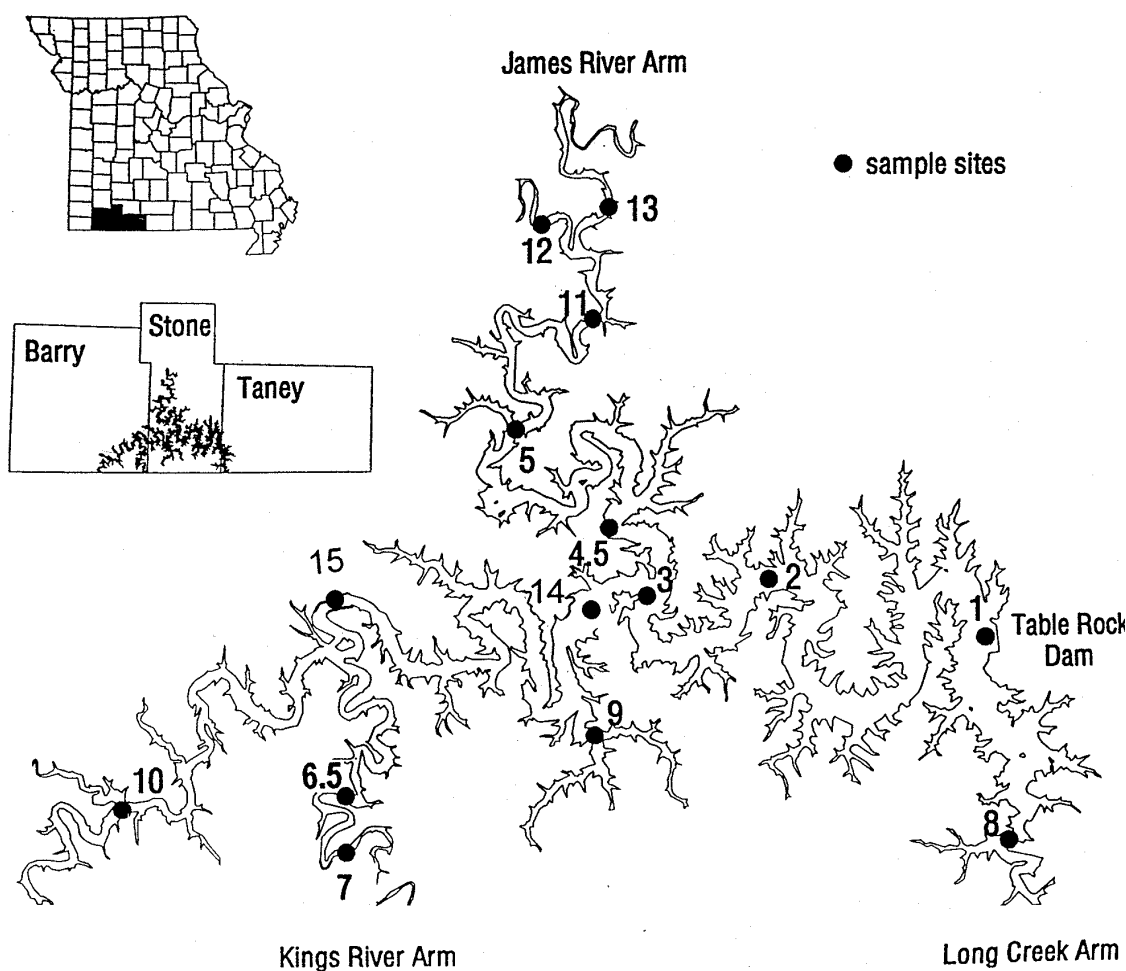


Figure 46. Location of Table Rock Lake sample sites.

Data was collected at 18 sites on Table Rock Lake during 1999. Monitoring was limited to Secchi transparency readings at three of the sites. Six Secchi readings were taken at the Viola site on the Kings River Arm. Sites at the mouths of Schooner and Fisher creeks (near Kimberling City) each had four Secchi readings recorded.

Sites monitored for all parameters had at least seven samples collected with the exception of Site 14 which was sampled six times and sites 5 and 11 which were each sampled twice. Due to the low number of samples, sites 5 and 11 were not included in the figures comparing sites across the lake.

Table 22. Trophic classifications for 1999 based on average phosphorus, nitrogen and chlorophyll values.

Main Lake Channel	Tributaries	James River Arm
Site 1 - oligotrophic	Site 6.5 - eutrophic	Site 4.5 - eutrophic
Site 2 - mesotrophic	Site 7 - eutrophic	Site 13 - eutrophic
Site 3 - mesotrophic	Site 8 - mesotrophic	
Site 14 - mesotrophic	Site 9 - mesotrophic	
Site 15 - mesotrophic	Site 12 - hypereutrophic	
Site 10 - mesotrophic		

- ▶ Conditions ranged from oligotrophic to hypereutrophic during 1999.
- ▶ Sites in the James River represent the full range of eutrophic conditions. (See page 8 for trophic criteria.) Site 13 was almost hypereutrophic while Site 4.5 was near mesotrophic conditions.

Table 23. Descriptive statistics from the main lake channel sites on Table Rock Lake - 1999.

Parameter		Site 10	Site 15	Site 14	Site 3	Site 2	Site 1
Nitrogen (µg/L)	average	359	276	437	441	336	286
	median	355	280	315	335	300	260
	minimum	250	220	230	200	220	180
	maximum	520	310	930	940	610	530
Phosphorus (µg/L)	average	16	13	13	12	13	9
	median	16	12	12	13	11	9
	minimum	12	11	8	8	9	6
	maximum	26	16	21	18	17	11
Chlorophyll (µg/L)	average	11.0	13.4	11.0	9.3	9.5	5.1
	median	7.5	13.1	11.7	9.5	8.9	4.2
	minimum	3.6	8.6	6.1	3.6	5.5	3.3
	maximum	27.8	21.6	16.0	17.5	15.5	8.5
Secchi (inches)	average	88	74	67	81	91	127
	median	82	75	71	67	78	105
	minimum	61	60	56	48	60	84
	maximum	128	87	73	170	192	216

- ▶ Median nitrogen values were comparable for all main lake sites. Higher averages for sites 3 and 14 (and to a lesser extent sites 2 and 10) were due to early season samples with elevated nitrogen levels. Site 15 was not sampled until late June, so no elevated nitrogen values were recorded.
- ▶ Phosphorus values for the middle four main lake sites were extremely comparable. Site 10 had a little more phosphorus than the middle sites while levels were lower at the dam (Site 1).
- ▶ The highest chlorophyll values in the main lake channel occurred in the upper lake, with the maximum value being measured at Site 10. Site 15 had the highest average and median values. Moving towards the dam, chlorophyll values tended to decrease and become less variable.
- ▶ Secchi transparency readings reflected chlorophyll levels with the deepest Secchi readings corresponding to the lowest chlorophyll concentrations.
- ▶ Secchi readings taken at the mouths of Fisher and Schooner creeks averaged 85 and 87 inches respectively. These values were similar to the average at

nearby Site 2.

Table 24. Descriptive statistics from sites on the James River Arm of Table Rock Lake - 1999.

Parameter		Site 13	Site 11*	Site 5*	Site 4.5
Nitrogen (µg/L)	average	1184	713	550	533
	median	1040			375
	minimum	710	585	520	190
	maximum	2310	840	580	1020
Phosphorus (µg/L)	average	97	57	41	17
	median	88			15
	minimum	70	52	34	9
	maximum	137	62	48	31
Chlorophyll (µg/L)	average	37.4	35.3	23.1	10.8
	median	44.5			10.7
	minimum	2.6	25.5	21.3	5.0
	maximum	68.0	45.1	24.9	17.2
Secchi (inches)	average	36	35	43	69
	median	36			71
	minimum	31	32	37	53
	maximum	40	37	48	98

* These sites were only sampled twice so direct comparisons with other sites may not be valid.

- ▶ Nitrogen displayed a notable gradient in the James River Arm, with the average value at Site 13 being more than twice that found at Site 4.5.
- ▶ The gradient for phosphorus was more dramatic as the average for Site 13 was more than five times that of Site 4.5.
- ▶ Chlorophyll mimicked the nutrients with the average being 3.5 times higher at Site 13 than Site 4.5.
- ▶ Secchi readings were stable at Site 13, ranging only nine inches. Values at Site 4.5 were deeper but more variable.
- ▶ Average values for sites 5 and 11 were generally between those of sites 4.5 and 13.

Table 25. Descriptive statistics from tributary sites on Table Rock Lake - 1999.

Parameter		Site 12	Site 9	Site 8	Site 7	Site 6.5
Nitrogen ($\mu\text{g/L}$)	average	1375	424	385	681	418
	median	1190	310	260	735	340
	minimum	940	200	250	420	250
	maximum	2920	740	1050	940	840
Phosphorus ($\mu\text{g/L}$)	average	74	11	13	75	43
	median	36	11	12	71	29
	minimum	12	9	10	40	21
	maximum	323	13	21	124	131
Chlorophyll ($\mu\text{g/L}$)	average	75.3	8.8	9.2	36.3	16.5
	median	3.3	6.6	7.2	33.0	15.7
	minimum	0.8	3.9	4.1	4.6	6.8
	maximum	518.5	16.4	21.4	75.3	28.1
Secchi (inches)	average	41	102	75	28	47
	median	44	63	72	27	50
	minimum	14	52	54	10	24
	maximum	63	283	96	44	53

- ▶ Nitrogen concentrations varied widely in the tributaries. Some sites were comparable to the main lake sites while Site 12 in Flat Creek had the highest nitrogen reading in 1999.
- ▶ Sites 8 and 9 had phosphorus levels that were indistinguishable from the main lake values.
- ▶ Both Kings River sites (7 and 6.5) as well as the Flat Creek site (12) had phosphorus values well above the main lake sites.
- ▶ Chlorophyll levels at Site 7 in the Kings River were very comparable to Site 13 in the James River.
- ▶ The chlorophyll value of 518 $\mu\text{g/L}$ at Site 12 was the highest reading measured on Table Rock Lake (or any other lake) by the LMVP since the program began in 1992.
- ▶ The minimum Secchi reading of 10 inches at Site 7 corresponded to a chlorophyll value of 4.6 $\mu\text{g/L}$. This low chlorophyll reading suggests that soil materials in the water were impacting water clarity.

- ▶ Note the longitudinal gradient in the Kings River Arm (sites 7 and 6.5) for all parameters.
- ▶ Average Secchi reading at the Viola site on the Kings River was 62 inches. This value represents a gain of 15 inches in water clarity from Site 6.5.

Table 26. Trophic assessment of sites on Table Rock Lake based on average chlorophyll values.

Site	1992	1993	1994	1995	1996	1997	1998	1999
1		M	M	E	O	M	M	M
2		M	E	E	M	M	M	E
3	E	E	E	E	M	M	M	E
4.5				E	M	M	E	E
5	E	E		E	E	E	E	
6.5					E	E	E	E
7					E	E	E	E
8		M	E	E	M	M	E	E
9			E	E	M	M	M	E
10			M	E	M	M	M	E
11				E	E	E	E	
12				H	E	E	H	H
13				H	H	H	H	E
14								E
15								E

O = Oligotrophic

M = Mesotrophic

E = Eutrophic

H = Hypereutrophic

- ▶ Only four sites have been classified in the same trophic category each year.
- ▶ There does not appear to be any trends of changing trophic status across the lake. (See page 8 for more information on trophic assessments.)

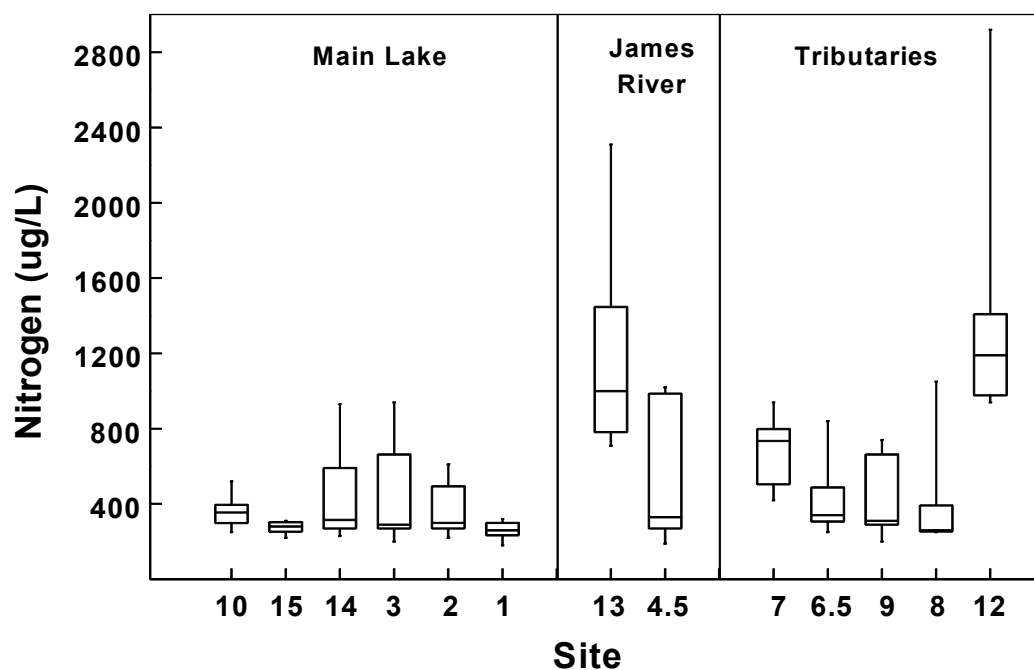


Figure 47. Nitrogen values for Table Rock Lake - 1999.

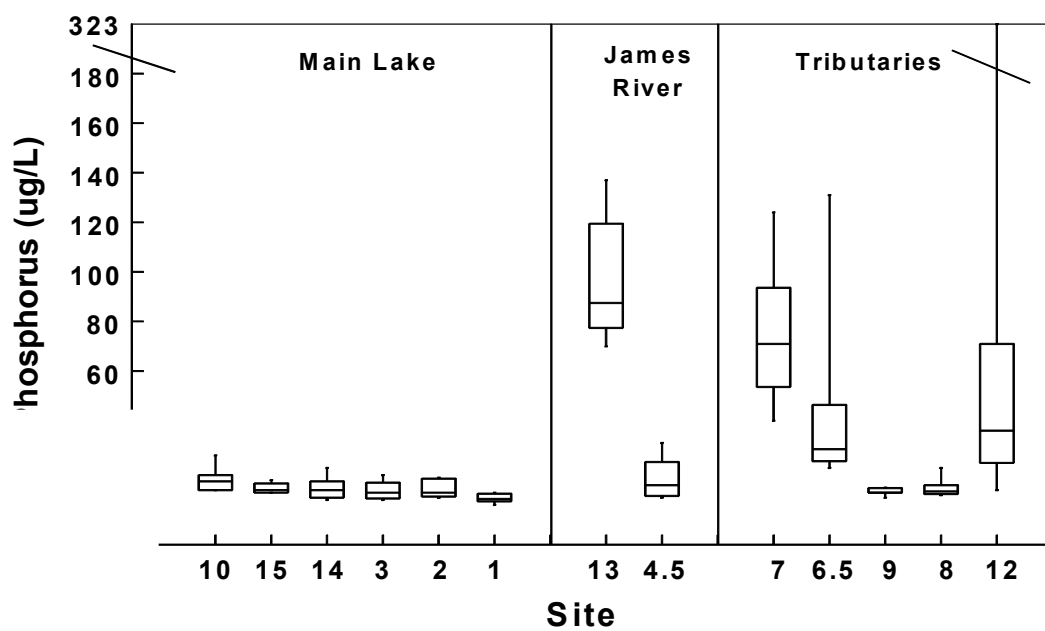


Figure 48. Phosphorus values for Table Rock Lake - 1999.

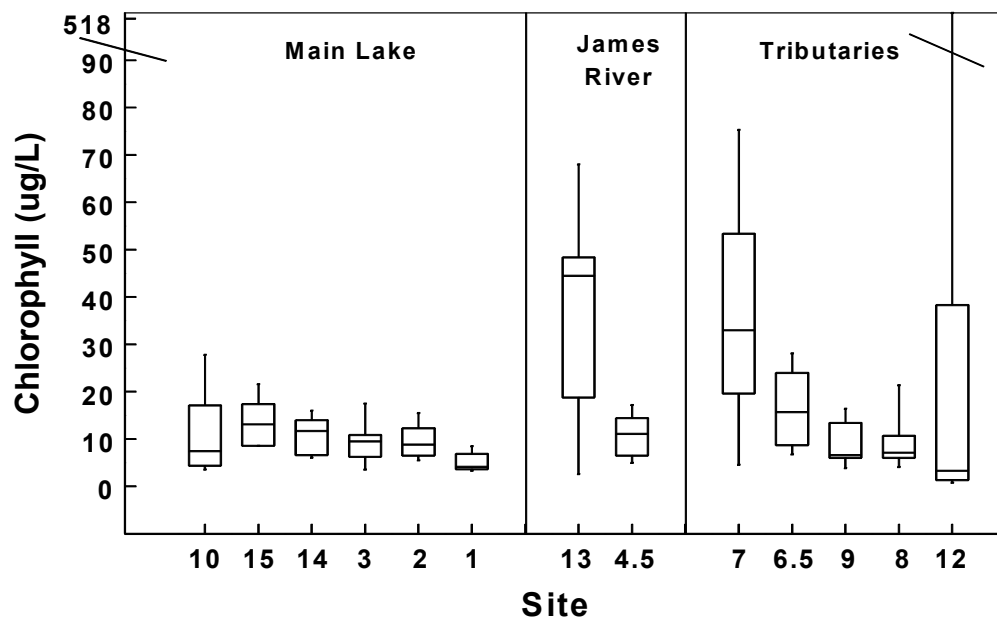


Figure 49. Chlorophyll values for Table Rock Lake - 1999.

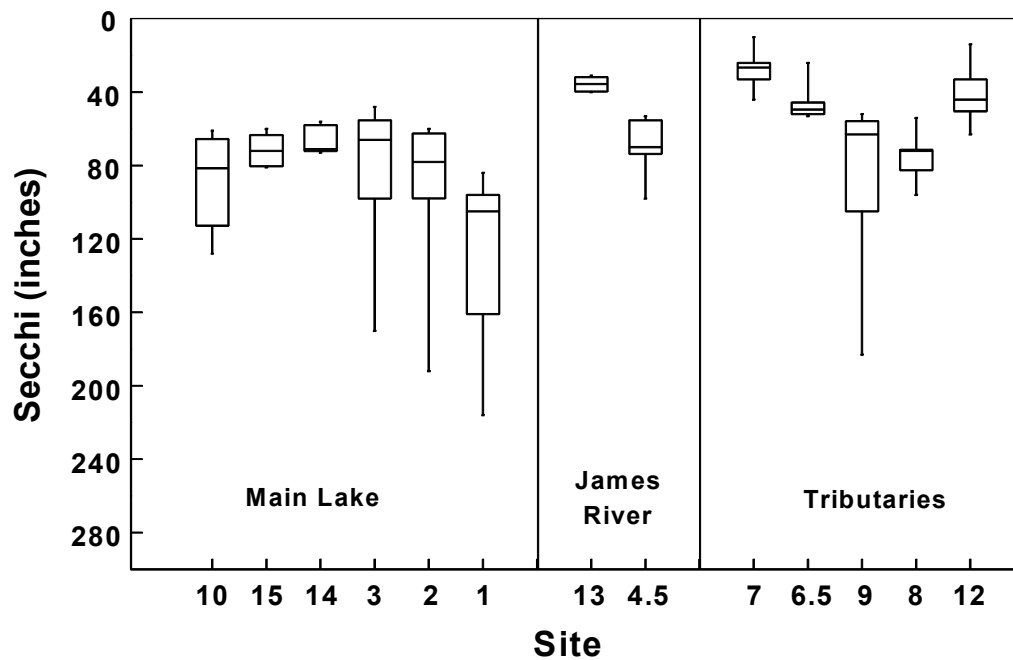


Figure 50. Secchi values for Table Rock Lake - 1999.

Table Rock Lake

Region - Ozark Highlands

Table Rock Lake is a 43,100 acre Army Corps of Engineers reservoir located in southwest Missouri. This lake is in the White River system and is preceded upstream by Beaver Lake in northwest Arkansas. The lake consists of a long, winding main branch and three major arms. Kings River and Long Creek flow north out of Arkansas to enter Table Rock Lake while the James River flows south from the central Ozark Highlands Region. The majority of the lake's watershed is forested, but development around the lake and urban areas on the lake's tributaries threaten water quality.

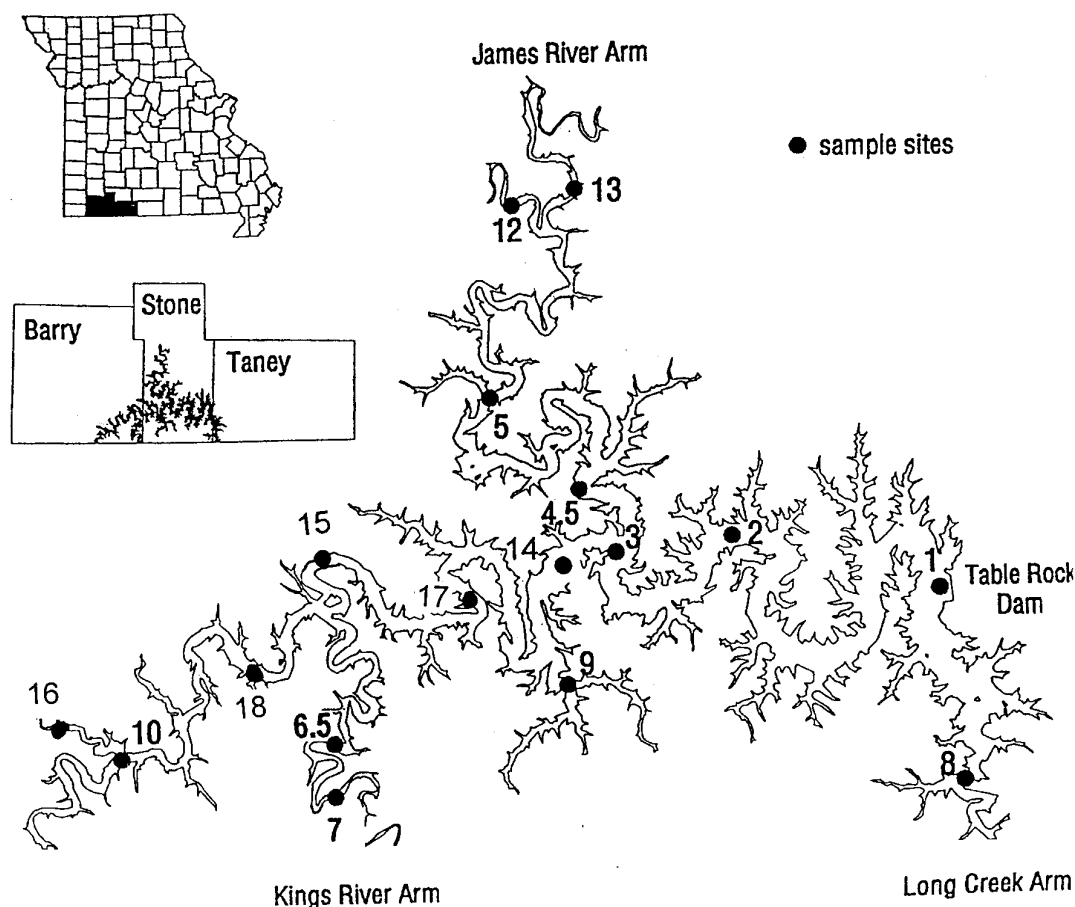


Figure 43. Location of Table Rock Lake sample sites.

- ▶ Data was collected at 17 sites on Table Rock Lake during 2000.
- ▶ Sites monitored for all parameters had at least eight samples collected with the exception of Site 16 which was sampled six times, Site 3 was sampled seven times and Site 10 was sampled five times.

Table 22. Trophic classifications for 2000 based on average phosphorus, nitrogen and chlorophyll values.

Main Lake Channel	Tributaries	James River Arm
Site 1 - mesotrophic	Site 6.5 - eutrophic	Site 4.5 - mesotrophic
Site 2 - mesotrophic	Site 7 - eutrophic	Site 5 - eutrophic
Site 3 - mesotrophic	Site 8 - mesotrophic	Site 13 - hypereutrophic
Site 14 - mesotrophic	Site 9 - mesotrophic	
Site 15 - mesotrophic	Site 12 - eutrophic	
Site 10 - mesotrophic	Site 16 - eutrophic	
Site 17 - mesotrophic		
Site 18 - mesotrophic		

- ▶ The trophic states from at least two out of three parameters were used to determine the trophic state of the site. All sites were either mesotrophic, eutrophic or hypereutrophic. No sites were in the oligotrophic range.
- ▶ Site 13 is the northern site in the James River Arm. There is a gradient from Site 13 to Site 4.5, the site closest to the main lake channel, of decreasing amounts of nutrients and algal chlorophyll.
- ▶ See page 78 for long term trend analysis.

Table 23. Descriptive statistics from the main lake channel sites on Table Rock Lake - 2000.

Parameter		Site 10	Site 18	Site 15	Site 17	Site 14	Site 3	Site 2	Site 1
Nitrogen ($\mu\text{g/L}$)	average	428	405	374	388	353	337	353	314
	median	410	400	370	365	345	330	375	310
	minimum	270	340	280	250	280	290	180	170
	maximum	660	510	520	520	450	410	510	470
Phosphorus ($\mu\text{g/L}$)	average	16	15	18	11	12	9	10	9
	median	15	13	16	11	12	10	10	9
	minimum	12	10	12	7	9	5	9	6
	maximum	22	23	29	19	15	12	13	14
Chlorophyll ($\mu\text{g/L}$)	average	6.5	6.5	6.1	4.5	2.9	5.0	4.3	3.4
	median	6.4	5.3	6.1	4.5	3.1	4.7	4.7	3.3
	minimum	4.5	3.5	4.2	2.9	2.1	3.4	2.1	2.0
	maximum	9.2	13.6	8.6	7.8	3.6	7.3	6.0	4.8
Secchi (inches)	average	79	85	115	110	114	112	136	151
	median	77	83	115	113	113	132	134	150
	minimum	72	72	91	63	72	53	117	123
	maximum	87	111	154	138	149	144	156	188

- Nutrient values show moderate variability at individual sites. Although values were relatively stable across the lake, there was a slight decrease in the average nutrient values from Eagle Rock (Site 10) to the dam (Site 1).
- Chlorophyll values had low to moderate variability at individual sites, but were comparable to each other.
- Note that the Secchi values demonstrate more variability than the chlorophyll. See page 64 for an explanation of this Secchi to chlorophyll relationship.

Table 24. Descriptive statistics from sites on the James River Arm of Table Rock Lake - 2000.

Parameter		Site 13	Site 5	Site 4.5
Nitrogen ($\mu\text{g/L}$)	average	980	536	371
	median	920	465	365
	minimum	560	330	240
	maximum	1540	1020	530
Phosphorus ($\mu\text{g/L}$)	average	179	30	12
	median	119	33	12
	minimum	76	18	9
	maximum	347	37	16
Chlorophyll ($\mu\text{g/L}$)	average	68.2	16.5	5.8
	median	66.7	17.8	5.5
	minimum	35.5	9.8	3.7
	maximum	109.0	22.1	9.8
Secchi (inches)	average	33	66	95
	median	33	61	95
	minimum	26	54	61
	maximum	39	112	139

- Values for Site 13 are quite variable for all parameters, excluding Secchi. While average nitrogen values are 2.5 to 3 times greater at Site 13 than the main lake channel, the phosphorus values are almost 20 times greater than some average values in the main lake channel.
- Note the longitudinal gradient with higher values at Site 13 which decrease moving down to Site 4.5. Values at Site 4.5 (Oswald Bluff) are comparable to the values in the main lake channel.

Table 25. Descriptive statistics from tributary sites on Table Rock Lake - 2000.

Parameter		Site 12	Site 16	Site 9	Site 8	Site 7	Site 6.5
Nitrogen ($\mu\text{g/L}$)	average	954	742	354	353	748	523
	median	815	830	340	360	690	535
	minimum	500	490	290	250	370	300
	maximum	1650	1000	480	430	1400	720
Phosphorus ($\mu\text{g/L}$)	average	54	32	12	13	101	51
	median	39	31	12	12	77	49
	minimum	11	26	10	9	57	26
	maximum	187	42	15	16	206	86
Chlorophyll ($\mu\text{g/L}$)	average	28.3	13.6	4.7	5.6	29.4	22.2
	median	2.3	13.0	4.6	5.7	28.2	21.5
	minimum	0.6	7.4	2.9	4.0	4.0	8.3
	maximum	155.6	19.9	7.3	8.0	60.3	36.7
Secchi (inches)	average	50	64	108	117	35	41
	median	43	66	102	120	31	40
	minimum	24	57	60	84	25	31
	maximum	93	70	168	150	55	62

- ▶ Site 12, located in Flat Creek off of the James River Arm near Cape Fair, had elevated values compared to the main lake channel. Due to dry spring and low lake levels, the volunteer was not always able to reach the site, therefore some samples were collected downstream of the site. Values from Site 12 were variable and comparable to those at Site 13.
- ▶ Sites 7 and 6.5, in the Kings River, have elevated values when compared to the main lake channel. Note the longitudinal gradient from Site 7 to Site 6.5. The average phosphorus value at Site 7 was over 10 times greater than the average phosphorus value measured at the dam (Site 1).
- ▶ Site 9 (Indian Creek) and Site 8 (Long Creek) have values similar to the main lake channel.
- ▶ Site 16, added this year, is in the Roaring River. All parameters, except Secchi, were approximately 1.5 to 2 times greater than the main lake channel.

Table 26. Trophic assessment of sites on Table Rock Lake based on average chlorophyll values.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000
1		M	M	E	O	M	M	M	M
2		M	E	E	M	M	M	E	M
3	E	E	E	E	M	M	M	E	M
4.5				E	M	M	E	E	M
5	E	E		E	E	E	E		E
6.5					E	E	E	E	E
7					E	E	E	E	E
8		M	E	E	M	M	E	E	M
9			E	E	M	M	M	E	M
10			M	E	M	M	M	E	M
11				E	E	E	E		
12				H	E	E	H	H	E
13				H	H	H	H	E	H
14								E	O
15								E	M
16									E
17									M
18									M

O = Oligotrophic

M = Mesotrophic

E = Eutrophic

H = Hypereutrophic

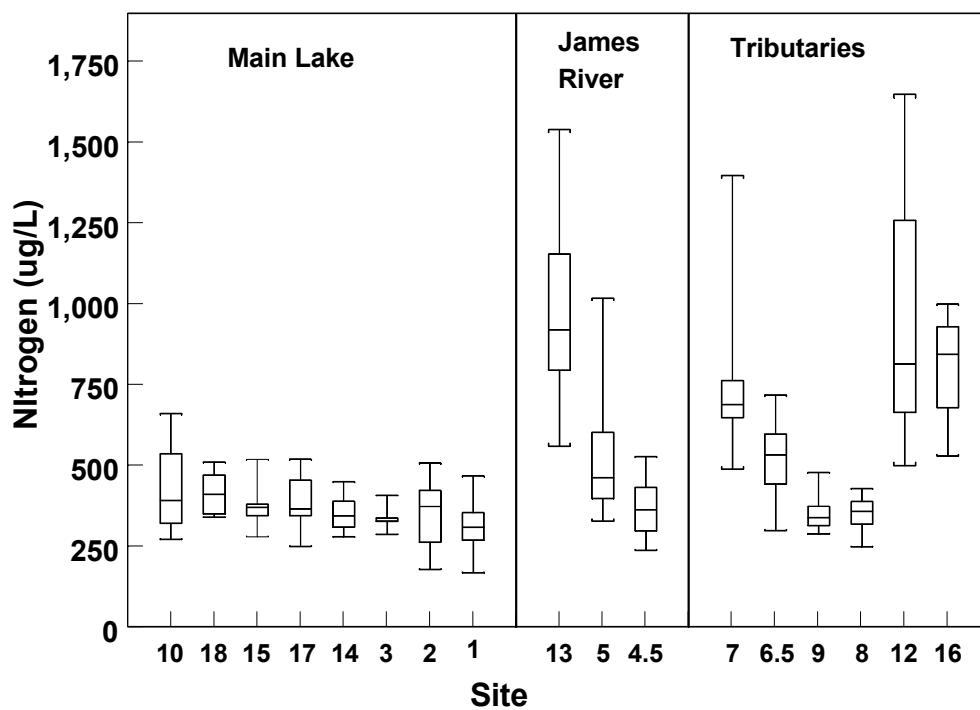


Figure 44. Nitrogen values for Table Rock Lake - 2000.

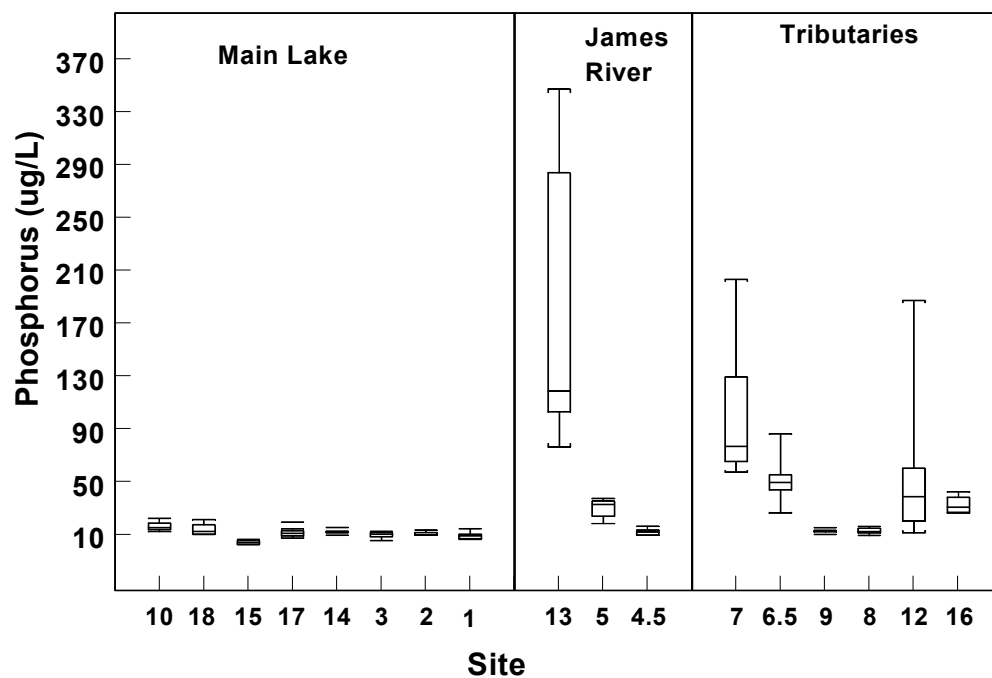


Figure 45. Phosphorus values for Table Rock Lake - 2000.

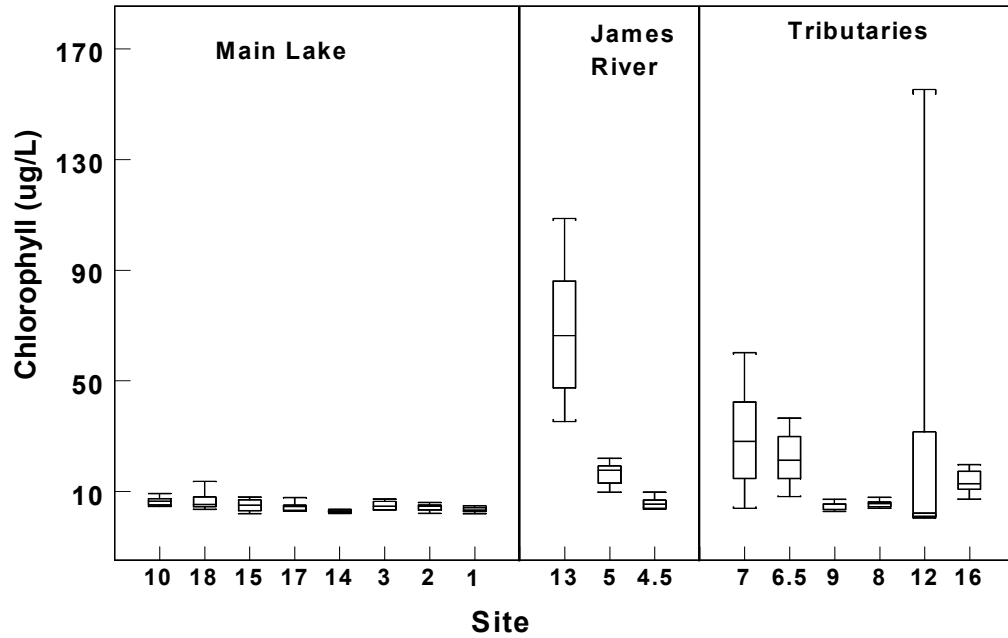


Figure 46. Chlorophyll values for Table Rock Lake - 2000.

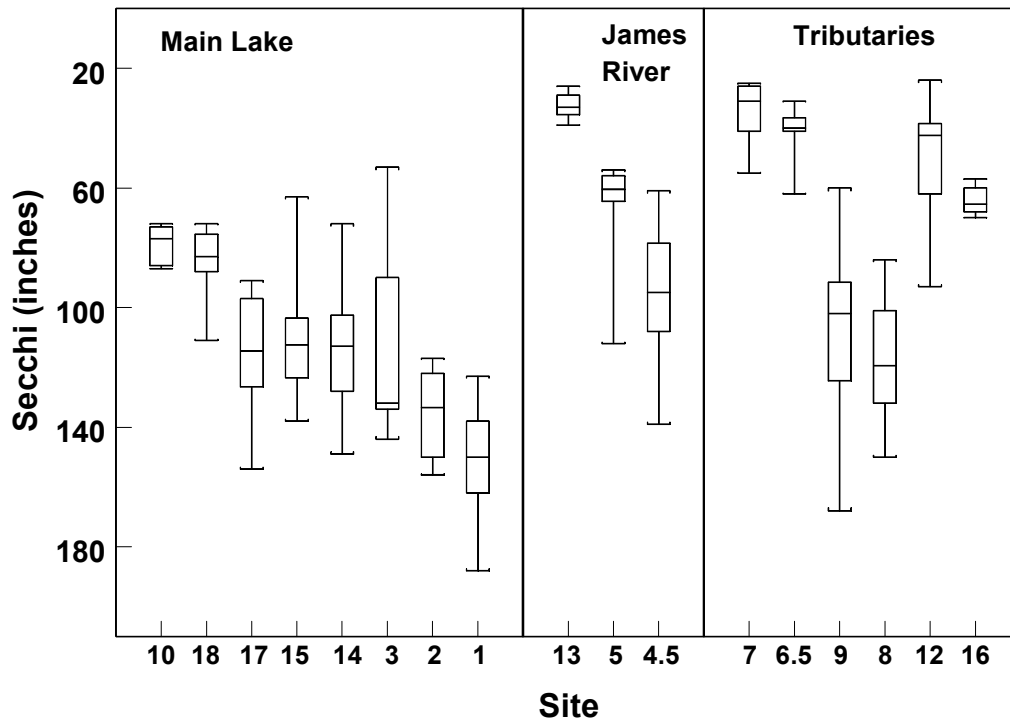


Figure 47. Secchi values for Table Rock Lake - 2000.

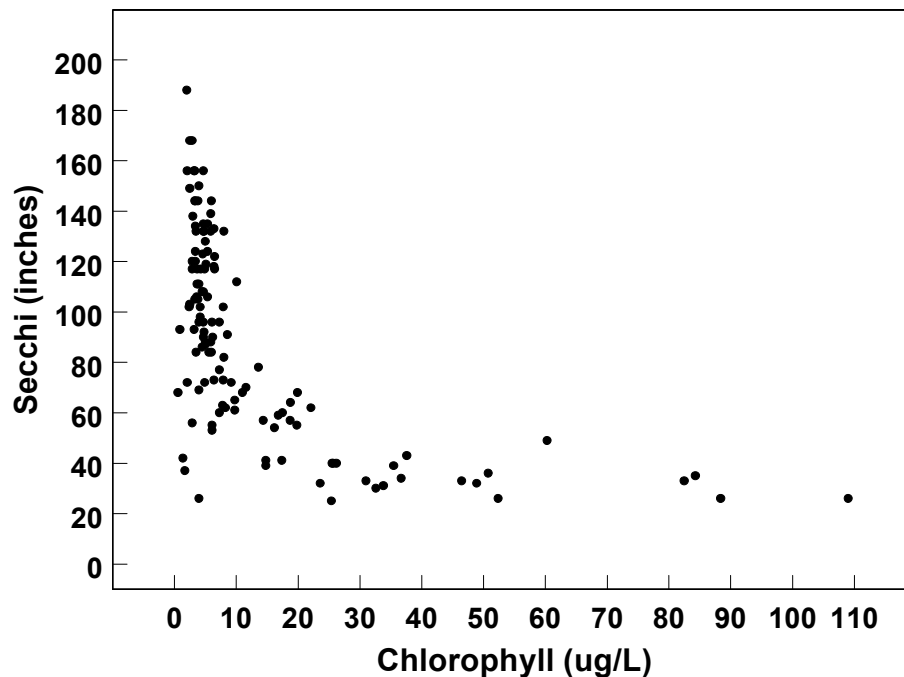


Figure 48. Chlorophyll-Secchi relationship for Table Rock Lake - 2000.

- ▶ Figure 48 shows the relationship between Secchi (water clarity) and volunteer chlorophyll data from the 2000 sample season.
- ▶ Relationship between chlorophyll and phosphorus is not a linear relationship.
- ▶ At low chlorophyll concentrations water clarity is much more sensitive to changes in chlorophyll. Note how Secchi can change from the 150 inch range down to the 80 inch range with very little change in the amount of chlorophyll.
- ▶ At higher chlorophyll concentrations, increases in chlorophyll do not lead to noticeable changes in water clarity. Note how relationship flattens out in the graph as chlorophyll values increase.
- ▶ Figure 48 is helpful to understand why the box plots in Figures 46 and 47 are not more alike, i.e. small changes in chlorophyll at low concentrations result in greater changes of water clarity.

Table Rock Lake - 2001 Data

Ozark Highlands Region

Table Rock Lake is a 43,100-acre Army Corps of Engineers reservoir located in southwest Missouri. This lake is in the White River System and is preceded upstream by Beaver Lake in northwest Arkansas. The lake consists of a long, winding main branch and three major arms. Kings River and Long Creek flow north out of Arkansas to enter Table Rock Lake while the James River flows south from the central Ozark Highlands Region. The majority of the lake's watershed is forested, but development around the lake and urban areas on the lake's tributaries threaten water quality.

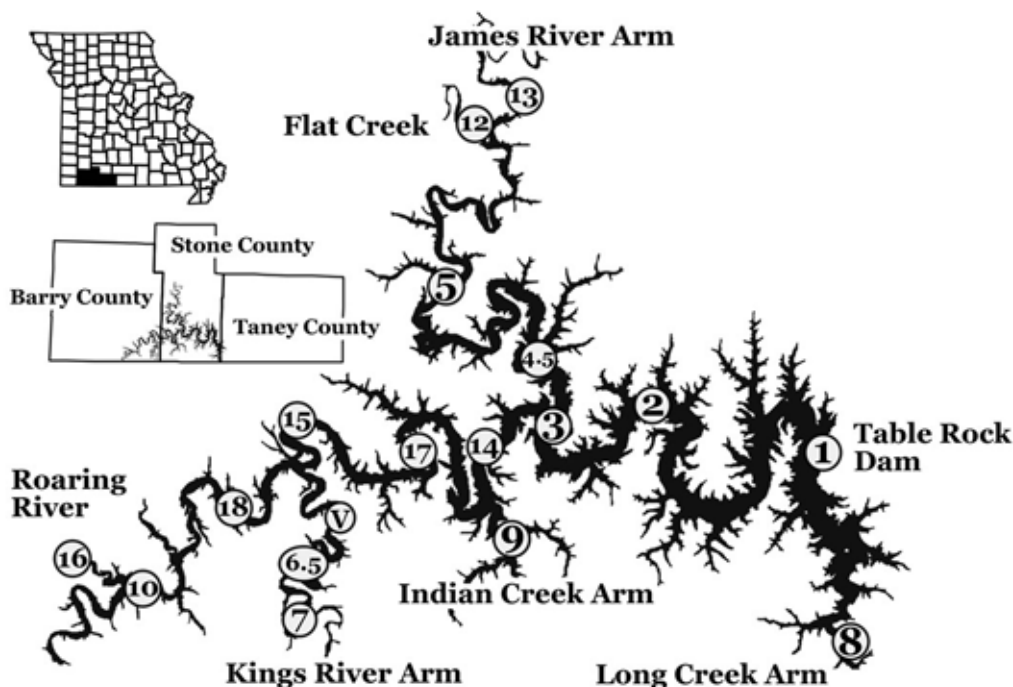


Figure 50. Location of Table Rock Lake and sample sites.

- Data were collected at 18 sites in 2001.
- Of these 18 sites, 8 were in the main channel, 3 each in the James River Arm and the King's River Arm, 1 each on Long Creek, Indian Creek, Flat Creek, and Roaring River.
- Only Secchi values were collected at Viola Access ("V" on the map).

Table 24. Trophic assessment of sample sites on Table Rock Lake, based on geometric mean values (note: these assessments are based on geometric means of *all* samples, not just summer samples)

Main Lake		Sample Sites							
		1	2	3	14	17	15	18	10
	Nitrogen	M	M	M	M	M	M	M	M
	Phosphorus	O	O	O	O	O	O	O	O
	Chlorophyll	O	O	O	O	O	O	O	O
James River and Kings River		Sample Sites							
		13	5	4.5	7	6.5			
	Nitrogen	E	E	M	M	M			
	Phosphorus	E	M	O	E	E			
	Chlorophyll	H	E	O	E	E			
Tributaries		Sample Sites							
		9	8	12	16				
	Nitrogen	M	M	E	E				
	Phosphorus	O	O	E	M				
	Chlorophyll	M	M	E	E				

O = Oligotrophic
M = Mesotrophic
E = Eutrophic
H = Hypereutrophic

Summary of Results for Table Rock Lake

Table 25. Descriptive statistics from the main lake channel sites on Table Rock Lake – 2001.

Parameters		Site 10	Site 18	Site 15	Site 17	Site 14	Site 3	Site 2	Site 1
Secchi Transparency (inches)	# samples	6	6	9	8	8	9	7	8
	geomean	130	163	159	177	172	233	206	235
	median	136	158	162	176	156	203	170	234
	minimum	110	141	93	142	123	175	147	192
	maximum	143	192	229	272	360	346	393	310
Phosphorus (mg/L)	# samples	6	6	8	8	5	9	7	8
	geomean	6	5	6	6	5	5	6	7
	median	7	6	6	6	5	6	6	5
	minimum	4	3	5	3	4	3	4	3
	maximum	9	8	9	12	8	7	8	24
Nitrogen (mg/L)	# samples	6	6	7	8	5	8	7	8
	geomean	312	348	360	432	333	327	392	337
	median	340	355	320	435	320	370	370	360
	minimum	160	230	190	220	220	120	240	160
	maximum	400	520	610	920	510	790	650	550
Chlorophyll (mg/L)	# samples	6	6	7	8	7	9	7	8
	geomean	2.3	2.2	2.6	3.4	2.5	1.3	1.7	1.9
	median	2.3	2.3	2.6	3.3	3.1	1.1	2.7	1.9
	minimum	1.7	1.4	1.5	2.1	0.9	0.5	0.2	1.3
	maximum	3.6	3.3	4.0	4.7	5.6	5.2	3.5	2.8

- Geometric mean nitrogen concentrations only varied between 312 and 432 µg/L, all mesotrophic values (Figure 51).
- Geometric mean phosphorus concentrations in the main lake varied between 5 and 7 µg/L, all oligotrophic values. Variability was low at all sites (range 3 – 12 µg/L) except Site 1, where values ranged from 3 – 24 µg/L (Figure 52).
- Geometric mean chlorophyll concentrations varied from 1.3 to 3.4 µg/L in the main lake. All sites except site 17 (concentration = 3.4 µg/L) were in the oligotrophic range for chlorophyll (Figure 53).
- Sample sites nearest the dam had higher Secchi values (Figure 54).
- At low concentrations of chlorophyll, a small decrease results in a large increase in Secchi transparency (see figures 95 and 96 in trends section)

Table 26. Descriptive statistics from the James River Arm of Table Rock Lake – 2001.

Parameters		Site 13	Site 5	Site 4.5
Secchi Transparency (inches)	# samples	8	8	8
	geomean	39	76	179
	median	40	78	164
	minimum	32	51	125
	maximum	47	123	265
Phosphorus (µg/L)	# samples	7	8	8
	geomean	87	12	5
	median	80	11	5
	minimum	67	7	2
	maximum	122	19	14
Nitrogen (µg/L)	# samples	8	8	8
	geomean	956	641	421
	median	885	690	415
	minimum	670	220	140
	maximum	1650	1760	1230
Chlorophyll (µg/L)	# samples	8	8	8
	geomean	49.0	9.9	2.9
	median	54.7	10.6	3.0
	minimum	26.6	4.5	1.0
	maximum	100.0	17.1	6.7

- Geometric mean phosphorus and chlorophyll values decreased by more than 16-fold from the site farthest upstream to the site closest to the main lake. Phosphorus and chlorophyll showed increasing variability with increasing distance from the main channel (Figures 52 and 53).
- Geometric means for phosphorus, chlorophyll and Secchi at site 4.5 were within the range of geometric means found in the main lake.
- Secchi values (and variability) decreased with increasing distance from the main lake channel, ranging from a geometric mean of 179 inches at site 4.5 to 39 inches at site 13 (Figure 54).

Table 27. Descriptive statistics from the Kings River and other tributary sites on Table Rock Lake – 2001.

Parameters		King's River Arm			Indian Creek	Long Creek	Flat Creek	Roaring River
		Site 7	Site 6.5	Site Viola	Site 9	Site 8	Site 12	Site 16
Secchi Transparency (inches)	# samples	8	8	8	7	8	8	8
	geomean	33	58	97	137	160	52	60
	median	34	53	92	135	153	46	64
	minimum	22	44	76	104	120	36	42
	maximum	42	95	147	220	252	157	75
Phosphorus (µg/L)	# samples	8	8	0	6	8	8	8
	geomean	77	26	X	6	8	27	24
	median	72	26	X	6	10	33	26
	minimum	61	17	X	3	2	4	8
	maximum	106	46	X	8	20	64	42
Nitrogen (µg/L)	# samples	8	8	0	6	8	8	7
	geomean	470	357	X	316	335	663	756
	median	460	335	X	265	365	615	755
	minimum	260	260	X	200	130	300	390
	maximum	870	770	X	700	640	1230	1590
Chlorophyll (µg/L)	# samples	8	8	0	6	8	8	8
	geomean	28.2	13.2	X	4.1	3.1	9.9	16.9
	median	27.8	13.0	X	4.5	3.5	18.0	16.4
	minimum	18.5	7.3	X	2.6	1.5	0.4	8.3
	maximum	49.1	33.3	X	6.1	5.1	42.8	37.6

- Geometric mean Secchi values in the King's River decreased threefold from the Viola access site (97 inches) to site 7 upstream (33 inches). There were no nutrient or chlorophyll samples taken from the Viola site, but the trend of decreasing Secchi and increasing nutrients with increasing distance upstream is seen between sites 6.5 and 7.
- The Flat Creek and Roaring River sites had 2 – 3 times higher geometric mean values for nutrients and chlorophyll than the Indian Creek and Long Creek sites.
- The Flat Creek and Roaring River sites had less than half of the geometric mean Secchi values of the Indian Creek and Long Creek sites.
- Indian Creek (site 9) and Long Creek (site 8) had geometric mean values similar to the main lake channel values. Flat Creek and Roaring River were more similar to the Kings River and James River sites.

Table 28. Trophic Assessment of sites on Table Rock Lake based on average chlorophyll values.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1		M	M	E	O	M	M	M	M	O
2		M	E	E	M	M	M	E	M	O
3	E	E	E	E	M	M	M	E	M	O
4.5				E	M	M	E	E	M	M
5	E	E		E	E	E	E		E	E
6.5					E	E	E	E	E	E
7					E	E	E	E	E	E
8		M	E	E	M	M	E	E	M	M
9			E	E	M	M	M	E	M	M
10			M	E	M	M	M	E	M	O
11				E	E	E	E			
12				H	E	E	H	H	E	E
13				H	H	H	H	E	H	H
14								E	O	O
15								E	M	M
16									E	E
17									M	M
18									M	O

O = Oligotrophic

M = Mesotrophic

E = Eutrophic

H = Hypereutrophic

- 2001 was the first year with more than one oligotrophic site. All oligotrophic sites were in the main lake.
- 1995 and 1999 were the most productive years, with eutrophic conditions across most of the lake.
- 12 of the 18 sites sampled at Table Rock lake have changed trophic state (based on chlorophyll averages) at least once in the last 3 years.
- None of the sites display a trend of changing conditions over time.

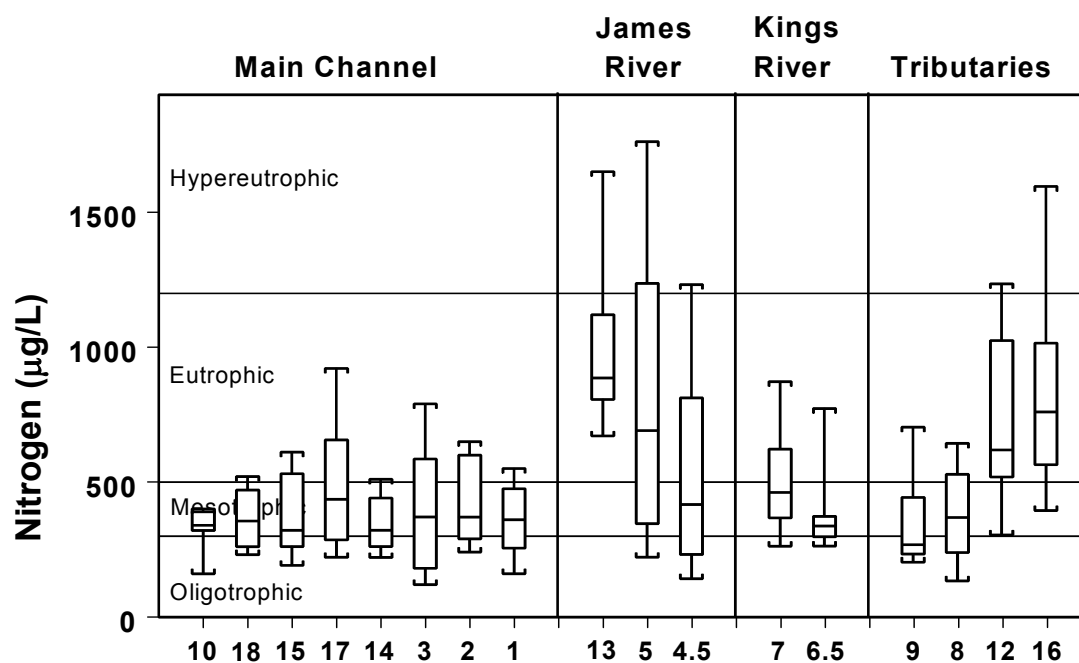


Figure 51. Nitrogen values for Table Rock Lake – 2001.

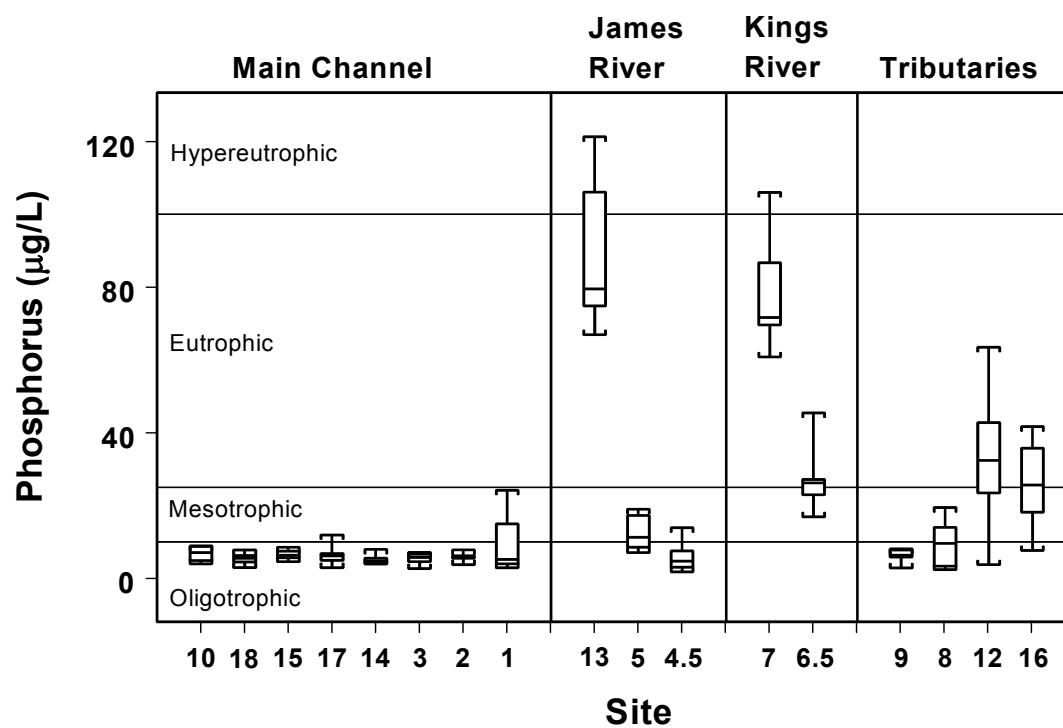


Figure 52. Phosphorus values for Table Rock Lake – 2001.

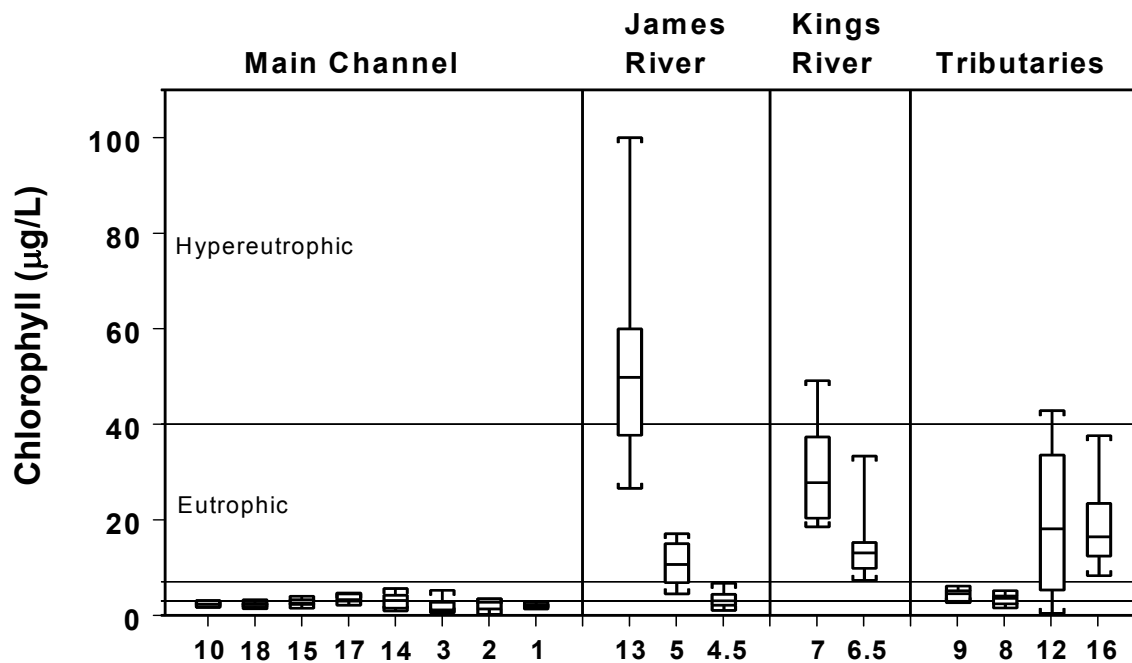


Figure 53. Chlorophyll values for Table Rock Lake – 2001.

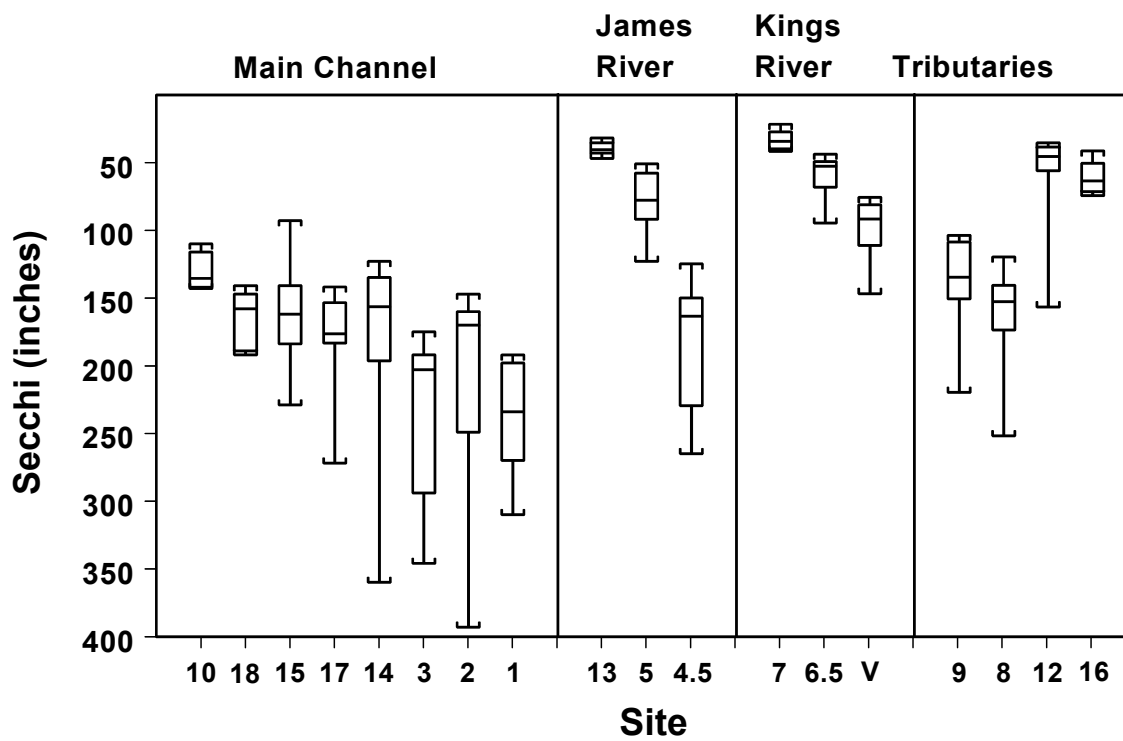


Figure 54. Secchi values for Table Rock Lake – 2001.

Table Rock Lake

Ozark Highlands Region

Table Rock Lake is a 43,100-acre Army Corps of Engineers reservoir located in southwest Missouri. This lake is in the White River System and is preceded upstream by Beaver Lake in northwest Arkansas. The lake consists of a long, winding main branch and three major arms. Kings River and Long Creek flow north out of Arkansas to enter Table Rock Lake while the James River flows south from the central Ozark Highlands Region. The majority of the lake's watershed is forested, but development around the lake and urban areas on the lake's tributaries threatens water quality.

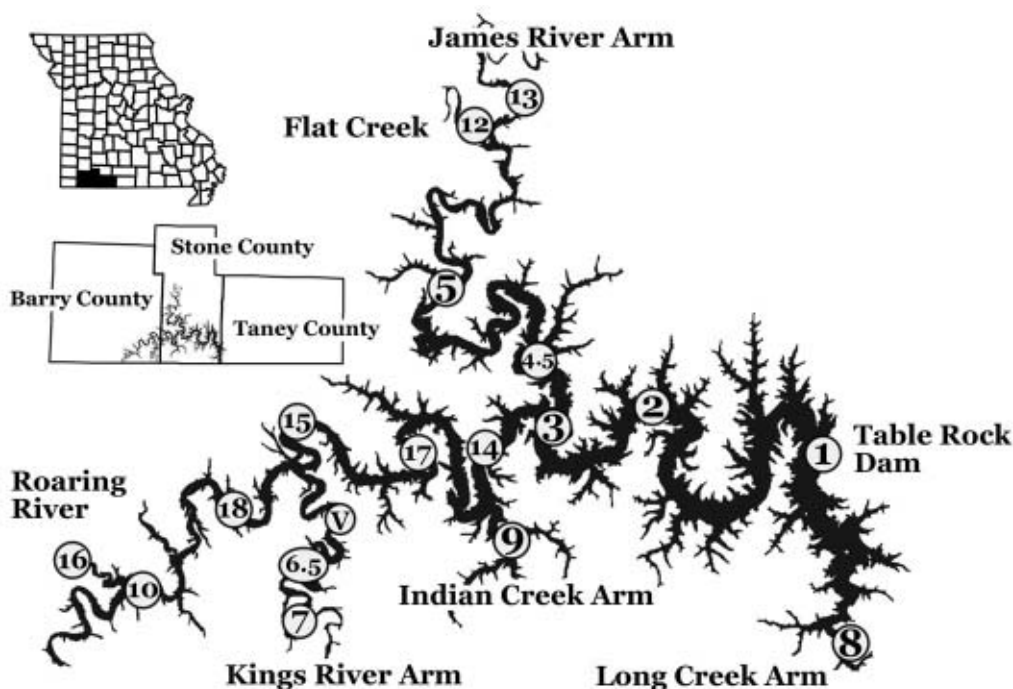


Figure 52. Location of Table Rock Lake and sample sites.

- Data were collected at 19 sites in 2002.
- Of these sites, nine were in the main lake, four in the James River arm, three in the Kings River arm, and one each in Long Creek, Indian Creek and Flat Creek.
- Secchi was the only parameter measured at the Viola access of the Kings River arm ("V" on the map).
- See the *Trends* section (page 85) for long-term analyses of Table Rock Lake data.

Table 25. Trophic assessment of sample sites on Table Rock Lake, based on geometric mean values (note: these assessments are based on geometric means of *all* samples, not just summer samples)

Main Lake		Sample Sites							
		1	2	3	14	17	15	18	10
	Nitrogen	M	E	M	M	M	M	M	M
	Phosphorus	O	M	M	M	M	M	M	M
	Chlorophyll	M	M	M	M	E	E	E	M

James River and Kings River		Sample Sites					
		13	11	5	4.5	7	6.5
	Nitrogen	E	E	E	M	E	M
	Phosphorus	E	E	E	M	E	E
	Chlorophyll	E	E	E	E	E	E

Tributaries		Sample Sites			
		9	8	12	16
	Nitrogen	M	M	E	E
	Phosphorus	M	M	E	E
	Chlorophyll	E	E	E	E

O = Oligotrophic
M = Mesotrophic
E = Eutrophic

Main Lake

- Based on nitrogen geometric means, all main lake sites (except site 2) are mesotrophic. Site 2 had a different sampling schedule, which probably skewed the results.
- All main lake sites, except Site 1, were mesotrophic based on phosphorus geometric means. This site was oligotrophic, though its geometric mean of 9 µg/L is very close to the mesotrophic cut point.
- Based on geometric mean chlorophyll values, main lake sites between Roaring River and Indian Creek (Sites 17, 15 and 18) were eutrophic, while the other main lake sites were mesotrophic.

Tributaries (including James River and Kings River)

- Sites 4.5, 6.5, 9 and 8 were mesotrophic based on nitrogen geometric means, while all other tributary sites were eutrophic.
- Sites 4.5, 8 and 9 were mesotrophic based on phosphorus geometric means, while all other tributary sites were eutrophic.
- All tributary sites were eutrophic based on chlorophyll geometric means.

Table 26. Descriptive statistics from the main lake channel sites on Table Rock Lake – 2002.

*Site 2 was sampled between January 28 and May 13 only and may not be comparable to other sites

Parameters		Site 10	Site 18	Site 15	Site 17	Site 14	Site 3	Site 2*	Site 1
Secchi Transparency (inches)	# samples	5	6	9	8	7	4	4	7
	geomean	82	51	59	63	79	89	127	125
	median	71	55	57	71	79	93	183	108
	minimum	56	32	27.0	30.0	57	69	122	60
	maximum	119	78	95.0	92.0	119	107	266	228
Phosphorus (µg/L)	# samples	5	6	8	8	7	4	4	8
	geomean	14	16	20	16	15	10	12	9
	median	13	17	17	13	16	10	13	10
	minimum	11	11	11	11	10	9	10	5
	maximum	21	24	69	46	23	12	21	12
Nitrogen (µg/L)	# samples	5	6	8	8	7	4	4	8
	geomean	443	398	416	390	479	415	605	476
	median	400	390	340	350	420	415	535	480
	minimum	320	280	300	250	330	390	450	370
	maximum	610	690	1190	860	830	440	1060	590
Chlorophyll (µg/L)	# samples	5	6	8	8	7	4	4	8
	geomean	6.6	9.0	11.7	10.2	5.1	5.8	4.7	4.8
	median	8.3	9.3	9.3	9.7	5.0	5.9	5.9	5.7
	minimum	2.1	4.8	4.8	5.4	1.4	4.3	0.8	2.3
	maximum	15.6	17.2	135.3	38.2	16.3	8.0	8.9	9.7

- After an initial decline in Secchi from Site 10 to Site 18, Secchi values increased toward the dam. At Sites 1 and 2, the increase in Secchi is dramatic, with maximums more than double those at any other site
- Phosphorus values are comparable across the main lake, with high maximum values at Sites 15 and 17 on April 22 (69 and 46, respectively)
- Nitrogen values tend to increase closer to the dam. This is likely due to the inflow from major tributaries such as the James and Kings river. The higher values at site 2 are likely due to the influence of Kimberling City, and the timing of the sampling.
- Main lake chlorophyll values were generally lower between the dam and Indian Creek compared to upstream of Indian Creek. The high value at Site 15 (135.3 µg/L) is the highest ever recorded by the LMVP for a main lake site at Table Rock Lake

Table 27. Descriptive statistics from the James River Arm of Table Rock Lake – 2002.

Parameters		Site 13	Site 11	Site 5	Site 4.5
Secchi Transparency (inches)	# samples	8	4*	4*	4*
	geomean	39	40	32	67
	median	38	33	43	62
	minimum	33	32	11	40
	maximum	54	54	56	132
Phosphorus (µg/L)	# samples	8	4	4	4
	geomean	67	27	31	8
	median	63	33	23	11
	minimum	59	23	16	2
	maximum	94	40	108	17
Nitrogen (µg/L)	# samples	8	3	4	4
	geomean	1045	523	683	310
	median	925	520	820	290
	minimum	650	450	290	106
	maximum	2060	560	1290	970
Chlorophyll (µg/L)	# samples	8	4	4	4
	geomean	21.3	13.1	21.9	11.4
	median	36.9	23.7	21.8	10.4
	minimum	0.7	15.6	14.0	6.3
	maximum	63.8	26.2	35.1	28.8

*Note the low number of samples for Sites 11, 5 and 4.5. Comparisons of values is difficult, as samples from Site 11 were taken late in the season while samples from Sites 5 and 4.5 were taken early in the season.

- The upper 3 sites have similar Secchi values (geometric means of 32 – 40 inches). The geometric mean at Site 4.5 is almost 70 inches, making this site comparable to the main lake.
- Phosphorus values show a longitudinal gradient, with values decreasing at sites closer to the main lake. Site 5 had a very high value for May 14. Other sites had high values on that date, indicating a storm event.
- Nitrogen and chlorophyll values generally decrease closer to the main lake.

Table 28. Descriptive statistics from the Kings River and other tributary sites on Table Rock Lake – 2002.

Parameters		Kings River Arm			Indian Creek	Long Creek	Flat Creek	Roaring River
		Site 7	Site 6.5	Site Viola	Site 9	Site 8	Site 12	Site 16
Secchi Transparency (inches)	# samples	8	8	9	7	7	8	8
	geomean	29	54	60	60	72	39	61
	median	36	56	58	61	78	40	60
	minimum	6	30	19	47	48	30	58
	maximum	44	83	168	86	111	56	66
Phosphorus (µg/L)	# samples	8	8		7	8	8	8
	geomean	52	27		16	16	46	27
	median	47	26		17	16	48	30
	minimum	37	15		13	10	16	12
	maximum	122	45		19	27	84	42
Nitrogen (µg/L)	# samples	7	8		7	8	8	8
	geomean	661	474		449	473	843	594
	median	610	440		430	365	790	565
	minimum	400	350		350	330	570	420
	maximum	1490	1030		610	870	1440	1160
Chlorophyll (µg/L)	# samples	8	8		7	8	8	8
	geomean	15.1	11.9		8.1	9.3	13.8	16.5
	median	18.8	15.2		8.0	9.9	26.9	19.4
	minimum	3.1	5.8		5.3	3.7	0.4	7.7
	maximum	42.3	22.3		13.1	18.8	55.4	34.5

- Kings River Arm sites show a trend of increasing clarity and decreasing nutrients nearer the main lake. Nitrogen and phosphorus values decrease from Site 7 to Site 6.5, with phosphorus approaching the cut point between mesotrophic and eutrophic. Chlorophyll values also decrease nearer the main lake.
- Flat Creek Secchi values are lower than those from Indian Creek, Long Creek or Roaring River tributary sites.
- Long Creek and Indian Creek phosphorus values are similar to the main lake and are considered mesotrophic based on geometric means. Sites at Roaring River and Flat Creek are higher than the main lake and are eutrophic, based on geometric means.
- Nitrogen values are similar among the Long Creek, Flat Creek and Roaring River tributary sites, and are considered eutrophic based on geometric means. Indian Creek has lower nitrogen values than the other sites and is considered mesotrophic based on the geometric mean.

Table 29. Trophic Assessment of sites on Table Rock Lake based on average chlorophyll values.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1		M	M	E	O	M	M	M	M	O	M
2		M	E	E	M	M	M	E	M	O	M
3	E	E	E	E	M	M	M	E	M	O	M
4.5				E	M	M	E	E	M	M	E
5	E	E		E	E	E	E		E	E	E
6.5					E	E	E	E	E	E	E
7					E	E	E	E	E	E	E
8		M	E	E	M	M	E	E	M	M	E
9			E	E	M	M	M	E	M	M	E
10			M	E	M	M	M	E	M	O	E
11				E	E	E	E				E
12				H	E	E	H	H	E	E	E
13				H	H	H	H	E	H	H	E
14								E	O	O	M
15								E	M	M	E
16									E	E	E
17									M	M	E
18									M	O	E

O = Oligotrophic
M = Mesotrophic
E = Eutrophic
H = Hypereutrophic

- Overall, there were higher chlorophyll values in 2002 relative to 2001.
- Site 13 was eutrophic for only the second time since monitoring began in 1995.
- Sites 17 and 18 had higher chlorophyll levels in 2002 compared to past years, but these sites have only been sampled for 3 years.

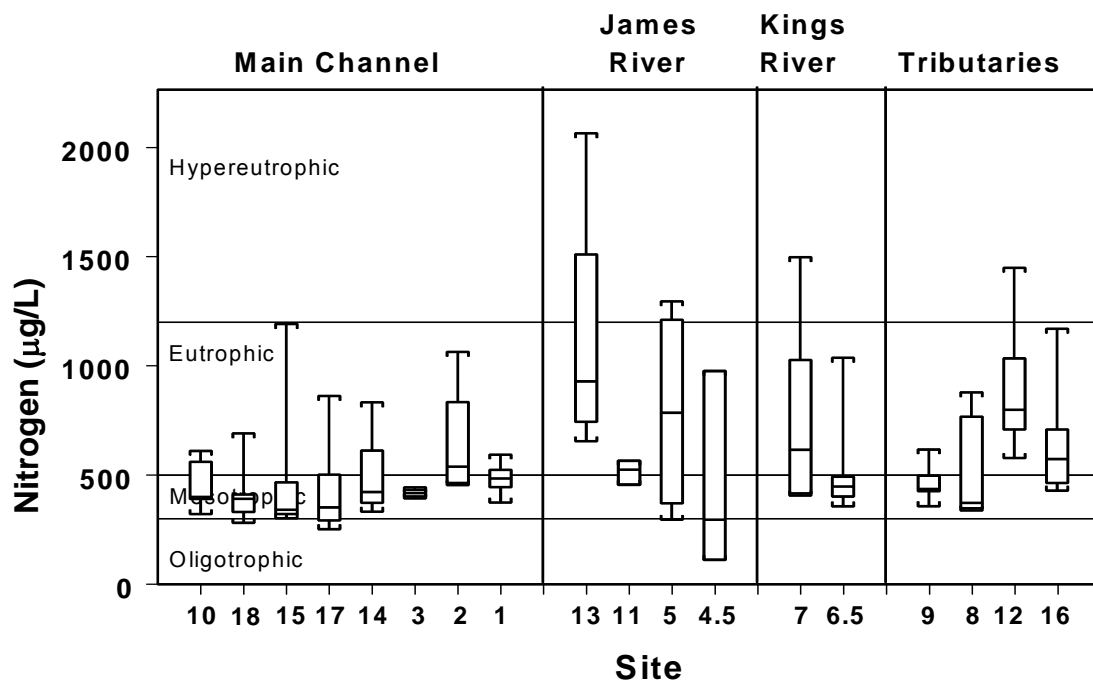


Figure 53. Nitrogen values for Table Rock Lake – 2002.

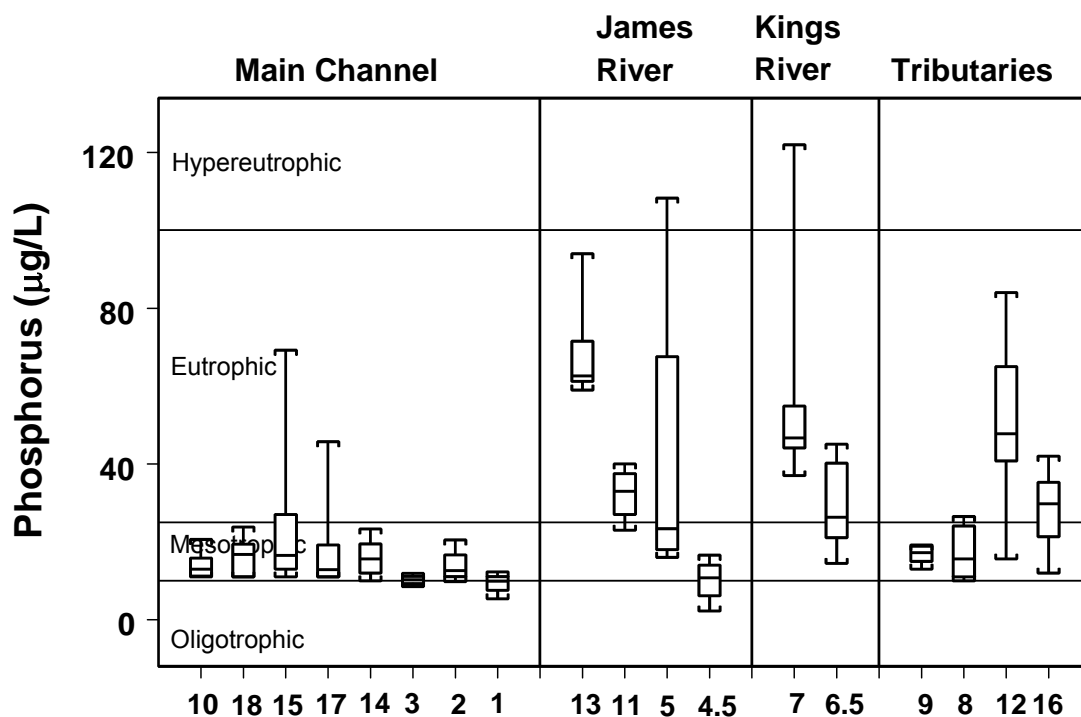


Figure 54. Phosphorus values for Table Rock Lake – 2002.

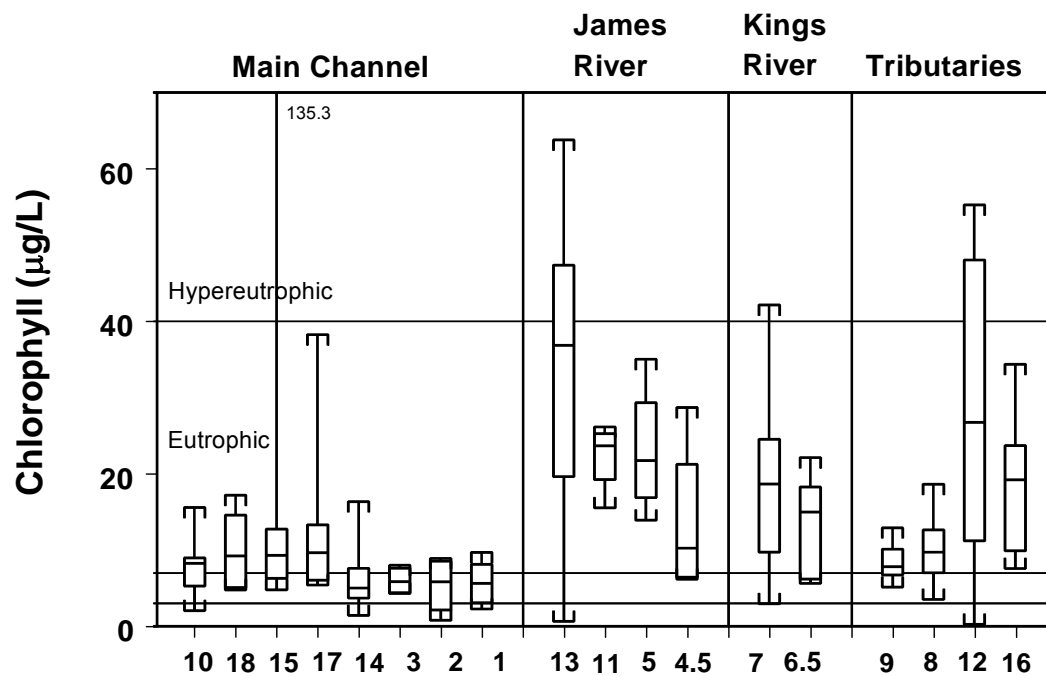


Figure 55. Chlorophyll values for Table Rock Lake – 2002.

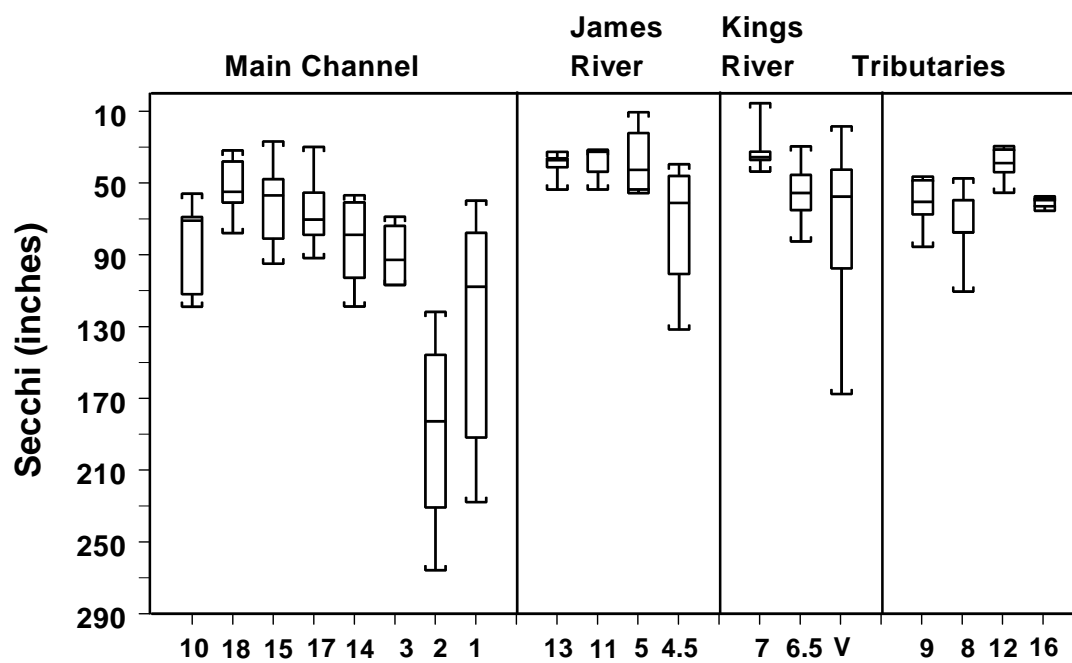


Figure 56. Secchi values for Table Rock Lake – 2002.